PROGRESSIVE APPROACHES TO CALCULATING BURNT AREA: OUTCOME OF JOINT WORKSHOP BY GDI AND CERCA

ABSTRACT

The burning of stubble in Punjab and Haryana's agricultural regions has become a critical environmental concern, increasing air pollution and posing risks to public health. This practice intensifies during the transition between harvesting and sowing seasons due to the need for rapid field preparation. Despite its convenience, stubble burning releases harmful pollutants, contributing to long-term environmental degradation and climate change. Efforts to tackle this issue are expanding, driven by the urgency to mitigate its impacts. Automatic detection of burned areas, reliant on satellite images, faces challenges due to data and methodological limitations. Alternative options for crop residue management are being promoted to dissuade farmers from burning stubble. A recent workshop held on February 16, 2024 organized by CERCA, IIT Delhi, and GDi highlighted key strategies and challenges in addressing stubble burning, emphasizing the need for collective action and innovative approaches.

I. INTRODUCTION

The practice of burning stubble, predominantly observed in the agricultural regions of Punjab, has emerged as a critical environmental issue with extensive implications [1]. This customary practice ingrained in the agricultural traditions of the area entails deliberately burning crop residues after harvesting, thereby substantially adding to air pollution and exacerbating prevailing air quality challenges. Within Punjab's fertile plains, characterized by the adoption of mechanized farming methods and extensive cultivation of crops like rice and wheat, a significant rise in stubble burning occurs during the transition between harvesting and sowing seasons. The imperative to rapidly prepare fields for the next planting cycle compels farmers to resort to the convenient yet environmentally detrimental practice of burning stubble [2]. The desire to swiftly transit from one crop to the next forces farmers to turn to burning as a cost-effective and time-saving solution. However, this practice inflicts a heavy toll on the environment by releasing harmful pollutants. This degradation in air quality not only poses immediate health risks to local communities but also contributes to long-term environmental deterioration and climate change.

The demand for proactive measures to tackle this issue is on the rise, driven by the pressing need to mitigate its adverse impacts on public health and the environment. However, addressing stubble burning is a multifaceted challenge, encompassing various issues ranging from the detection of burned areas to governance-related matters. Automatic detection of burned areas, a crucial step in combating stubble burning, often relies on satellite images. While satellite images are instrumental in this process, freely available data frequently lack one or more of the three essential resolutions: spatial, spectral, and temporal [3]. Furthermore, different remote sensing agencies and stakeholders use different methods for the burnt area estimation and the absence of a standardised methodology for burnt area calculation has resulted in significant variations in estimations. In addition to technological solutions, concerted efforts are underway to dissuade farmers from resorting to stubble burning by promoting alternative options for crop residue management. Various agencies are actively involved in advocating for sustainable practices that can contribute to combating air pollution.

Despite these efforts, addressing stubble burning comprehensively requires greater attention and collaboration from different stakeholders and they must work together synergistically to develop holistic strategies that address the complexities of this issue effectively. Towards this CERCA, IIT Delhi and GDi partnered to organize a workshop on February 16, 2024. The primary objective of the workshop was to facilitate focused brainstorming sessions among stakeholders from different domains for the development of a methodology to effectively calculate the area burnt after crop residue burning. This whitepaper summarizes the key takeaways from this workshop.

The rest of the whitepaper is organized as follows. Section II provides the overview of the workshop/event. Key findings are outlined in Section III. Recommendations and potential next steps are discussed in Section IV. Finally, we conclude in Section V.

II. WORKSHOP OVERVIEW

The half-day workshop took place on February 16, 2024 at IIT Delhi premises. The event was started with brief introductory notes on behalf of CERCA and GDi. Following this, the following speakers shared their experiences in 15 minutes talk each about different aspects related to burned area mapping:

1) **Sudipan Saha, IIT Delhi:** mainly presented their joint work with ITC Limited in the context of burnt area mapping in Kapurthala, Punjab. They have adopted normalized difference BA index (NDBI) [3] in their work and limited evaluation has shown it to be partly effective, though extensive testing is required. The speaker also stressed on the importance of adopting multi-temporal approach for burnt area mapping.
2) **Ritesh Kumar, Haryana Space Application Center (HARSAC):** talked about their binary (burnt/unburnt) classification approach using support vector machine. They mentioned several challenges w.r.t. their approach, including misclassification of water bodies, requirement of training data, and parameter tuning.
3) **Harpinder Singh, Punjab Remote Sensing Center (PRSC):** talked about their approach that mask out unwanted classes like buildup forests, waterbodies etc. and then perform unsupervised clustering to get many classesand calculate Normalized Burn Ratio (NBR) using Sentinel-2 in conjunction with MODIS and VIIRS data.
4) **Namrata Kala, MIT Sloan School of Management:** talked about a Payments for ecosystem services(PES) approach to incentivize farmers to not engage in stubble burning. They used two modes of payment: upfront and postpay. Furthermore, to monitor stubble burning, they used PlanetScope images in conjunction with Random Forest method.
5) **Mohammad Rafiuddin, COUNCIL ON ENERGY, ENVIRONMENT AND WATER (CEEW):** talked about Burned Area Index for Sentinel-2 (BAIS2) [4], however he noted that the index is highly sensitive to threshold.
6) **Somajita Paul and Manoj Singh, The Nature Conservancy (TNC) :** talked about their analysis at the village level using MODIS data. They furthermore mentioned that out of almost 19K villages in their study area, 2500 contributes more than 75% burning incident.
7) **Jayanarayanan Kuttippurath, IIT Kharagpur :** talked about using several approaches Normalized Difference Vegetation Index (NDVI) and NBR. He also talked about uncertainty in threshold and issues related to validation. Furthermore, he mentioned about issues related to cloud in optical images and alternative use of SAR, e.g., Sentinel-1 images.

Following the presentations, a 45-minute discussion and brainstorming session ensued, engaging various participants, notably Dr. Vinay Sehgal from IARI. Dr. Sehgal emphasized several critical aspects, including the imperative to comprehensively understand the impact of stubble burning on air pollution and the need for temporally and spatially varying thresholds in detection methods. He suggested that a combination of indices, coupled with a decision tree approach, could be effective in delineating burned areas. He also commented that incentive-based approaches need to refrain from offering compensation merely for following the law. Multiple speakers raised concerns regarding the suitability of machine learning techniques for burned area mapping, citing challenges such as the scarcity of high-quality training data. Dr. Murthy from MNCFC also stressed on understanding the volume of the stubble burning versus merely calculating area. Furthermore, the discussion delved into governmental considerations, highlighting the possibility that farmers may have adapted their burning practices to evade detection by commonly used sensors like Sentinel-2. This acknowledgment emphasized the complexity of addressing stubble burning and the importance of integrating various perspectives in devising effective solutions.

III. KEY FINDINGS

Here are some technical key findings from the presentations and the discussions in the workshop:

1) **Limited temporal resolution:** Despite offering superior spatial and spectral resolution compared to MODIS, Sentinel-2 falls short in terms of temporal resolution, posing a significant challenge, especially in monitoring stubble burning. With a revisit period of 5 days, which may not always be adequate for timely detection, Sentinel-2's capabilities are constrained in effectively tracking stubble burning events.
2) **Limited spatial resolution:** Despite the superior spatial resolution of Sentinel-2 in comparison to sensors like MODIS, it does not provide detailed spatial information like very high resolution images.
3) **A variety of indices work to some extent:** According to various agencies and academic institutions, different burnt area indices appear to perform to some extent in terms of effectiveness.
4) **Importance of thresholding:** Irrespective of the exact index used, the thresholding remains a key challenge to automatically delineate the burnt pixels.
5) **Temporally and spatially varying threshold:** As emphasized by multiple speakers, establishing the threshold for identifying burnt pixels must consider the month or season of the year, as the sensitivity of different indices fluctuates over time. Similarly, it's crucial for indices to incorporate the geographical context and may need to be adjusted based

on spatial location. This point emphasizes the dynamic nature of environmental factors influencing burnt area detection and highlights the importance of tailoring detection methodologies to account for temporal and spatial variations.

6) **Pre-filtering may be helpful:** Filtering out known non-agricultural land classes can be helpful to improve effectiveness of the burnt area calculation. In this regard, the remote sensing agencies may consider to publish crop layers.
7) **Understanding source of pollution:** It is yet not well understood exactly how much the stubble burning contributes to the air pollution in the region. It is important to understand this aspect and should be handled in future research works.

Here are some of the governance related takeaways from the workshop:

1) **Farmers optimizing burning practices:** The challenges related to temporal resolution are further exacerbated by the likelihood that farmers are optimizing their burning practices based on the image acquisition dates of widely used sensors. This optimization strategy entails timing stubble burning activities to coincide with periods when satellite passes are less frequent or when there is a higher likelihood of cloud cover hiding the view of the ground. By strategically aligning their burning practices with these factors, farmers may seek to evade detection and enforcement efforts, thereby complicating monitoring and mitigation initiatives.
2) **Incentive-based methods:** Incentive-based methods need to be designed in a way such that compensation is not offered simply for following the law.
3) **Volume of stubble burning:** Ideally, the policies must be framed keeping in mind the volume of the stubble burning and not merely the burnt area. This emphasizes the necessity to devise methods related to this.

IV. RECOMMENDATIONS

Based on the discussions in the workshop, here are some of the recommendations:

1) Combining Sentinel-2 data with observations from complementary sensors presents an opportunity to improve the temporal resolution of burned area detection. Through the compilation of a time-series dataset incorporating data from various sensors, researchers can attain a more holistic understanding of burnt areas over time. By leveraging the strengths of multiple sensors and their respective temporal coverage, this strategy enhances the reliability and effectiveness of burnt area monitoring efforts, thereby advancing our ability to assess and manage environmental impacts associated with stubble burning. Furthermore, this may also mitigate the issues related to farmers temporally optimizing their burning practices.
2) Establishing accurate thresholds to differentiate between burned and unburned areas requires a deep comprehension of the spatiotemporal dynamics of fire occurrence. Conducting extensive studies across broader geographic regions will valuable insights into historical fire activity patterns. This will also facilitate the development of context-specific thresholds customized for individual regions and varying seasons.
3) Evaluating the potential benefits of utilizing advanced techniques for estimating stubble burnt areas necessitates a comprehensive investigation into the relationship between burning events and air pollution levels. By gaining deeper insights into this correlation, researchers can better assess the effectiveness of advanced methods in accurately quantifying stubble burning occurrences. Understanding how burning incidences contribute to air pollution will enable policymakers and stakeholders to make informed decisions regarding mitigation strategies and regulatory measures.
4) Collection of accurate ground truth data may be helpful to mitigate several issues, including for training machine learning models.
5) Using very high resolution (VHR) satellite images may alleviate some of the issues related to spatial resolution of the burnt area mapping. Furthermore, some VHR sensors are also available at very good temporal resolution. However, the accessibility of such images is often constrained by their high cost. Therefore, it is suggested that government and private agencies evaluate the feasibility of acquiring VHR imagery, taking into account budgetary considerations.

V. CONCLUSION

The half-day workshop held on February 16, 2024, at the premises of IIT Delhi brought together experts and stakeholders to delve into the complexities of burnt area mapping and stubble burning management. The event commenced with introductory remarks from CERCA and GDi, setting the stage for insightful discussions. Speakers from diverse backgrounds shared their experiences and research findings, shedding light on various approaches and challenges associated with burnt area mapping. Several determination aspects were discussed, including indices to detect burnt pixels, threshold determination, and usage of machine learning methods. Similarly, several governmental aspects were discussed, including usage of incentives to dissuade farmers from stubble burning. Following the presentations, a lively discussion ensued, focusing on several aspects including understanding the impact of stubble burning on air pollution, the need for temporally and spatially varying thresholds, and the

potential of combining indices with a decision tree approach for delineating burned areas. Discussions were made regarding the suitability of machine learning techniques for burnt area mapping and the need to understand the volume of stubble burning rather than just calculating the area. Additionally, governance-related issues such as farmers optimizing burning practices and the design of incentive-based methods were discussed. Overall, the workshop provided valuable insights and recommendations for advancing burnt area mapping and stubble burning management efforts, emphasizing the need for collaborative approaches and interdisciplinary research endeavors.

DECLARATION

This whitepaper was compiled by Dr. Sudipan Saha on behalf of CERCA, IIT Delhi, with contributions from GDi. The content of this article does not represent the author's personal views but rather a collection of points that emerged during the workshop.

VI. REFERENCES

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